Infants’ Use of Material Properties to Guide their Actions with Differently Weighted Objects

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Two studies with 9-, 11- and 13-month-old infants were conducted to investigate infants’ ability to use an object’s material properties to guide their object-directed actions. In study 1, 9- and 11-month-old infants played in an exploration phase with two objects made of different materials, one very heavy and the other one light and playable. Subsequently, when given the choice between both objects in a preferential reaching task, only the 11-month-olds used the object’s material information to remember and choose the lighter object. In study 2, 11- and 13-month-old infants underwent the same exploration phase. In the test phase, novel objects made of the same materials were offered. The 13- but not the 11-month-olds chose the objects made from the same material as the lighter object in the exploration phase. Additionally, infants’ performances in the reaching task were positively correlated with their exploratory behaviour during the exploration phase. Altogether, the studies show a developmental progression in the use of an object’s material information to guide infants’ action. The results are discussed in respect to infants’ perception of object properties and their implications for the development of physical knowledge. Copyright © 2010 John Wiley & Sons, Ltd.

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One important step in human development is to learn about the properties of the physical environment and how to use these to guide actions. Studies using the violation-of-expectation method and thus relying on visual processing have...
revealed important insights into infants’ developing physical knowledge (e.g. Baillargeon, 2002; Wilcox, 1999). But how do infants use this information to guide their own actions?

Perception–action accounts of sensorimotor development have established that objects are rich in information about the actions they afford (cf. Adolph, Eppler, & Gibson, 1993; Gibson, 1988; Gibson & Pick, 2000; Lockman, 2000). In the course of their development, infants learn about this information among others through perception–action routines, which are optimized towards the different information provided by the objects. Indeed, within their first year of life, infants have acquired behaviours, which help them to gather information about a variety of object properties. For example, it could be shown that infants squeeze soft objects more than rigid ones or that they scratch objects more, when they are textured, when compared with non-textured objects (e.g. Bourgeois, Khawar, Neal, & Lockman, 2005; Bushnell & Boudreau, 1998; Fontanelle, Kahrs, Neal, Newton, & Lockman, 2007; Palmer, 1989; Rochat, 1987).

Material properties are very important aspects in our interaction with objects and include object characteristics such as texture, rigidity and compliance (e.g. Klatzky & Lederman, 1993). For example, knowing that a rigid and heavy object serves best as a paperweight, we would certainly prefer to use a cube of iron instead of a soft sponge. Empirical research has confirmed that adults use material information to adapt, for example, their movement time (Fikes, Klatzky, & Lederman, 1994) and to guide their reaching movements (Fleming, Klatzky, & Behrmann, 2002). Taken together, it can be concluded that material information is an important property of the physical world, which is often used to guide our object-directed actions. But surprisingly little is known about the developmental changes in children’s use of material information to guide their actions.

Studies concerning perceptual development have provided evidence that infants from a young age are able to differentiate between different material properties (e.g. Gibson & Walker, 1984; Molina & Jouen, 2003, 2004; Sann & Streri, 2007; Stack & Tsonis, 1999; Striano & Bushnell, 2005). Importantly, infants also integrate material information into their own play behaviour (Bourgeois et al., 2005; Palmer, 1989). Bourgeois et al. (2005), for example, demonstrated that infants in the second half of their first year of life act differently towards objects and surfaces, when these differ in material (e.g. a soft object on a rigid surface or vice versa). This suggests that infants tailor their actions to the materials of these objects. The above-mentioned studies provided valuable insight into infants’ handling of material information but leave open the question, from which age infants use material properties also in an anticipative manner (cf. von Hofsten, 2004, 2007). In other words, when do infants start to use material information to choose objects, given that material is the only indicator of potential actions the object affords?

Two studies were conducted to examine this question. Based on previous research that had shown that infants display a strong preference for the lighter of two objects when both objects are offered to them at the same time (e.g. Hauf, Paulus, & Baillargeon, 2010), we were interested in investigating from which age infants would use information about an object’s material to identify the lighter object. In particular, we were interested whether infants would be able to use material information to remember the lighter and thus more interesting (i.e. playability in terms of affordances for possible actions) of two objects (Experiment 1) and to infer the playability of novel objects made of the same material as the lighter object (Experiment 2). To this end, infants in both the experiments played with two objects. One of the objects was very light so that it afforded a lot of actions like lifting it into the air and the other one was so heavy that infants
could not easily manipulate it (e.g. Belsky & Most, 1981; Haufl et al., 2010; Ruff, 1984). Afterwards, in four test trials, two objects were presented to the infants, which were either identical or similar with respect to the material of the two objects that infants played within the exploration phase. By measuring their preferences for one of the two objects (preferential reaching technique; cf. Hespos & Baillargeon, 2006), we aimed at discovering how infants use material information to guide their actions with differently weighted objects.

EXPERIMENT 1: MATERIAL

The first experiment investigated the infants’ use of material information to remember and choose the lighter of two differently weighted objects. Research on infants’ manual actions on objects has indicated that by 8 months infants encode the weight of objects into their play behaviour with different objects (e.g. Itier, Provasi, & Bloch, 2001). Furthermore, it has been shown that children from 9 months onwards use colour information to remember the weight of an object (e.g. Mash, 2007) and to subsequently choose the lighter of two objects (Haufl et al., 2010). Based on these earlier findings, we examined 9- and 11-month-old infants in Experiment 1.

METHOD

Participants

The final sample consisted of 32 healthy term infants. Sixteen 9-month-old infants (eight girls and eight boys) and sixteen 11-month-old infants (eight girls and eight boys) participated in the study. The 9-month-olds were on average 9 months and 9 days old (S.D.: 5 days; range: 9 months 0 days to 9 months, 14 days). The 11-month-olds were on average 11 months and 3 days old (S.D.: 4 days; range: 10 months and 25 days to 11 months and 9 days). Twelve additional infants were tested but were not included in the final sample because of refusal to touch one or both objects during the exploration phase, refusal to remain seated or because they did not look at the test stimuli or did not demonstrate a clear reaching behaviour in at least three of four test trials.

Test Environment, Apparatus and Stimuli

The test room was unfurnished except for the test equipment. In order to cover the technical equipment and to minimize infants’ distraction, the room was kept with neutral surroundings. The objects used during the exploration phase were four yellow cubes: two of them made out of Styrofoam and two made out of sponge. Pilot studies had revealed no major preference for one or the other material. Each cube had an axis of 10 cm. By inserting lead, a light cube (around 200 g) and a heavy cube (around 2000 g) were produced for each material. Additionally, a blue-coloured plank was used. A slice of each material was fixed on this ‘sensation plank’ to familiarize children with the texture of the different materials. Additionally, this allowed for a direct comparison of both materials simultaneously, enhancing thus infants’ sensitivity to the different material properties. During the test trials, a blue wooden platform (50 × 10 × 2.5 cm) with two mounted cubes was presented. The experimenter used a blue screen (30 cm
high and 60 cm wide) preventing infants to watch the experimenter while preparing each novel test trial. The mounted cubes were identical to the ones infants played with in their exploration phase (see Figure 1).

**Procedure**

Infants were tested in our laboratory at a time of day when they were likely to be alert and playful. During a warming-up phase in a playroom, the experimenter outlined the experimental procedure to the parents and enabled the infant to get familiarized with him/her. Then, the infant and parent were brought to the test room and the infant was given approximately two more minutes to acclimate to that environment. The parent and experimenter faced each other across a test table (122 × 124 cm). Each infant sat on a parent’s lap at the test table in a cut-out area 30 cm wide and 33 cm deep with the experimenter sitting on the opposite side of the table. Parents were instructed to hold their infants at the hips and to remain silent and neutral during the trials. As soon as the infant seemed

![Figure 1. Stimuli used during exploration phase (1) and test phase (2) in the material memory (Exp. 1) and the material transfer experiment (Exp. 2). The left and middle panels display the sensation plank as well as the yellow sponge and yellow Styrofoam cube of the exploration phases of Experiments 1 and 2. The right panel shows the test plank with the yellow sponge cube and the yellow Styrofoam cube used in the test phase of Experiment 1. A yellow sponge house and a yellow Styrofoam house were mounted on one test plank used in the test phase of Experiment 2. A yellow sponge pyramid and a yellow Styrofoam pyramid were mounted on the other test plank of Experiment 2.](image)
comfortable, the experiment began. The experiment consists of one session that was divided into an exploration phase and a test phase.

**Exploration phase**

First, the sensation plank was presented to the infants for 30 s to enable the infants to feel and see both materials at a time. During the subsequent first exploration trial, the experimenter placed one of the cubes on the table in front of the infant and encouraged the infant to play with it. After 45 s, the experimenter removed the cube. In the second exploration trial, the experimenter placed the other cube on the table in front of the infant and encouraged the infant to play with it. After 45 s, the experimenter removed the cube again. The cubes were presented sequentially to give the infants the possibility to explore every object on its own and to prevent infants from neglecting one of the objects. The experimenter always grasped the cube with both hands ensuring that the grip did not indicate the weight of the cubes. The combination of material and weight was counterbalanced across infants as well as the order of presentation.

**Test phase**

The test phase consisted of four trials and followed immediately after the exploration phase. Each trial started with the screen in the centre of the table. The experimenter lifted the screen in order to reveal the two cubes mounted on a blue platform and put the screen behind the platform on the table. The experimenter slid the platform forward until it stood 40 cm from the cut-out area, still out of the infant’s reach, waited 3 s and pushed the platform towards the infants, stopping just at the edge of the infant’s reaching space, to encourage reaching with one hand instead of two. This way the infants were prevented from reaching for both objects and the whole platform simultaneously with both hands and were thus, in effect, forced to make a choice. The infant was given up to 15 s to respond; during that time, the experimenter looked at the centre of the platform to avoid inadvertently cueing the infant. As soon as the infant reached for one of the cubes, the experimenter cheered and pulled the platform out of reach avoiding infants feeling the weight of the cubes or manipulating them during testing. The experimenter then moved the screen in front of the platform to prepare the next trial. Four test trials were conducted with each infant. The positions of the Styrofoam and sponge cubes were reversed across trials; the order in which these positions were presented was counterbalanced across infants. Two video cameras recorded the infant’s reaching behaviour. One camera captured a side view of the infant, and the other camera was fixed to the left of the experimenter in order to capture the experimenter’s hands, the infant’s torso, head and hands as well as the most of the tabletop. The images of both cameras were combined using a video mixer.

**Data Analysis**

Two independent observers, who were blind to which cube was heavier for each infant, scored each videotaped session. For the exploration phase, a primary coder measured how long they were manually engaged with each cube overall, and how much of this time they spend with behaviours that could yield information about the cube’s weight: pushing the cube along the surface of the table, lifting the cube in midair, tipping the cube so that one end was off the table,
mouthing the cube and slapping the cube with the hand. A secondary coder independently scored 25% of the infants in Experiments 1 and 2 on their behaviours in the exploration phase; correlation coefficients ranged from $r = 0.95$ to 0.99. The data from the six dependent measures (time spent engaged, pushing, lifting, tipping, mouthing and slapping each cube) were entered into a 2 (age: 9 or 11 months) × 2 (weight: lighter or heavier cube) multivariate analysis of variance (MANOVA) with repeated measures on the last factor.

On each test trial, the coders determined whether the infant reached the Styrofoam or sponge cube. Trials with discrepancies between the coders were viewed for a second time and resolved through frame-by-frame analysis. This occurred on less than 3% of the trials. Children who refused to reach at all together in more than two trials were excluded from the analysis for the reason of lacking interest, so that from each participant data from at least 3 trials were obtained. For statistical analysis, measures were averaged over the test trials for every participant. Infants’ percentage correct was calculated from the number of reaches to the light cube out of the total number of reaches (e.g., when an infant reached in three of the four trials; this yields a score of 75%; when an infant reached in two of the three trials; this yields a score of 67%). If not stated differently, two-tailed $t$-tests against chance (i.e., reaching for the light object in 50% of the cases) were used to determine the infants’ preferences for one of the two objects in the test phase.

**RESULTS**

**Exploration Phase**

This analysis yielded a main effect of weight, $F(6, 25) = 8.324, p < 0.001, \eta^2_p = 0.67$. Subsequent univariate analyses (corrected using the Huynh–Feldt procedure) revealed that the infants spent significantly more time in lifting, $F(1, 30) = 24.163, p < 0.001, \eta^2_p = 0.45$ and tipping the lighter cube, $F(1, 30) = 7.745, p < 0.01, \eta^2_p = 0.21$. Importantly, however, overall infants were likewise manually engaged with both cubes, $F(1, 30) < 1$. No other significant main or interaction effects were found (all $p$s > 0.10). On average, infants spent 35.52 s (S.D. = 7.90) playing with the lighter cube, and 56% of that time (19.88 s, S.D. = 8.63) was spent in weight-relevant behaviours (see Table 1); infants spent 35.36 s (S.D. = 7.35) touching the heavier cube, and 27% of that time (9.70 s, S.D. = 6.72) was spent in weight-relevant behaviours. The results clearly indicate that the infants had ample opportunity to explore both objects and to detect the different weights.

**Test Phase**

During the test phase, the 9-month-old infant showed no clear preference for any cube. They reached to the light cube in 52% of all trials, $t(15) = 0.222, p = 0.828$ (see Figure 2). In contrast, the 11-month-old infants showed a significant preference for the light cube; they reached for this object in 69% of the trials, $t(15) = 3.503, p < 0.01$. A direct comparison of the two age groups revealed a significant difference between the 11-month-old and the 9-month-old infants’ test performances, $t(30) = 1.947, p < 0.05$, one-tailed.

Next, it was examined whether infants’ behaviours during the exploration phase correlated with their performance in the test phase. As only the 11-month-old infants displayed a systematic pattern in Experiment 1, we examined the
To compute the time infants spent in weight-relevant behaviours during the exploration phase with each of the cubes, the time they spent in pushing, slapping, lifting, mouthing and tipping each cube was summed (see Table 1). Infants’ test performance was positively correlated with the time they treated the light cube with weight-relevant behaviours ($r = 0.52$, $p < 0.05$), but not the heavy cube ($r = 0.21$, $p = 0.43$). Importantly, there was no correlation between infants’ test performance and the time they were generally engaged with the light ($r = 0.13$, $p = 0.63$) or the heavy cube ($r = -0.05$, $p = 0.86$).
This indicates that the more time infants spent in weight-relevant behaviours during the exploration of the light, the more likely they were to choose the lighter cube in the test phase.

The results demonstrate differences between 9-month-old and 11-month-old infants’ use of material information to guide their actions. Only the 11- but not the 9-month-olds were able to employ information about an object’s material to subsequently identify the lighter of two objects.

EXPERIMENT 2: MATERIAL TRANSFER

The first experiment revealed that 11-month-old but not 9-month-old infants use material information to remember the more playable object. This leads to the question, at what age infants might be able to generalize this property to other objects made of the same material. To this end, Experiment 2 consisted of the same exploration phase; however, instead of presenting the same cubes in the test phase again, novel objects made of the same material were presented. As in Experiment 1, only the 11- but not the 9-month-old infants used material information to remember an object’s weight, we examined 11-month-old infants (see also Hauf et al., 2010). We additionally included 13-month-old infants in Experiment 2 to investigate developmental effects as recent findings provided evidence for developmental differences between 11- and 13-month-old infants’ processing of visual object information for subsequent object-directed action (Barrett & Needham, 2008).

METHOD

Participants

The final sample consisted of 32 healthy term infants. Sixteen 11-month-old infants (eight girls and eight boys) and sixteen 13-month-old infants (eight girls and eight boys) participated in the study. The 11-month-old infants were on average 11 months and 3 days old (S.D.: 6 days; range: 10 months and 19 days–11 months and 13 days). The 13-month-old infants were on average 13 months and 1 day old (S.D.: 14 days; range: 12 months and 4 days–13 months and 22 days). Five additional infants were tested but were not included in the final sample because of refusal to touch one or both objects during the exploration phase or refusal to remain seated.

Test Environment, Apparatus and Stimuli

The test environment, procedure and material were identical to those used in Experiment 1, with only one difference. During the test phase, two blue-coloured planks (50 × 10 × 2.5 cm) were used instead of only one. Two yellow houses made of Styrofoam and sponge were mounted on one of the test planks; two yellow Styrofoam and sponge pyramids were mounted on the other one. All objects had similar volumes (see Figure 1).

Procedure

The procedure was the same as in Experiment 1, with a slight difference in the test phase. During the test phase, two test planks were presented. The
experimenter offered one test plank during the first and second test trial (e.g. the houses) and the other plank during the third and fourth test trial (e.g. the pyramids) in an ABBA sequence with respect to the spatial position of the materials (e.g. Styrofoam object right, sponge object left). Four test trials were conducted with each infant. The combination of material and weight was counterbalanced across infants as well as the order of presentations and which test plank was presented first.

RESULTS

Exploration Phase

This analysis\(^1\) yielded a main effect of weight, \(F(6, 25) = 4.107, p = 0.005, \eta^2_p = 0.50\). Subsequent univariate analyses (corrected using the Huynh-Feldt procedure) revealed that infants spend significantly more time in lifting the lighter cube, \(F(1, 30) = 24.013, p < 0.001, \eta^2_p = 0.45\). Importantly, however, overall infants were likewise manually engaged with both cubes, \(F(1, 30) = 2.378, p = 0.13, \eta^2_p = 0.07\). No other significant main or interaction effects were found (all \(p’s > 0.09\)). On average, infants spent 30.00 s (S.D. = 11.03) playing with the lighter cube, and 57% of that time (16.99 s, S.D. = 10.90) infants demonstrated weight-relevant behaviours (see Table 1); infants spent 27.01 s (S.D. = 8.74) playing with the heavier cube, and 25% of that time (6.71 s, S.D. = 7.33) was spent in weight-relevant behaviours. The results clearly indicate that the infants had ample opportunity to explore both objects and to detect the weights accordingly.

Test Phase

During the test phase, the 11-month-old infants showed no clear preference for any object. They reached to the object made of the same material as the light object in the exploration phase in 52% of the trials, \(t(15) = 0.269, p = 0.80\) (see Figure 2). In contrast, the 13-month-old infants showed a significant preference for the objects made of the same material as the light object in the exploration phase. They reached for it in 63% of all trials, \(t(15) = 3.162, p < 0.01\). A direct comparison of the two age groups revealed that the difference between 11- and 13-month-old infants performances approached significance, \(t(30) = 1.557, p = 0.065,\) one-tailed.

The findings illustrate that the 13- but not the 11-month-old infants used the material information of an object to infer the playability of novel objects made of the same material, even though they saw these objects for the first time.

As in Experiment 1, we examined whether infants’ behaviours during the exploration phase was correlated with their performance in the test phase. As only the 13-month-olds displayed a systematic pattern in Experiment 2, we examined only this age group’s performance. No significant correlation was found between infants’ test performances and the time they were overall engaged with the light cube \((r = 0.18, p = 0.50)\) or the heavy cube \((r = 0.69, p = 0.11)\). A direct comparison of the amount of time spent in weight-relevant behaviours with the light cube between the infants who reached for the light cube in more than 50% of the trials (22.55 s, S.D. = 9.89) and the infants who reached for the light cube in precisely or less than 50% of the trials (12.50 s, S.D. = 9.71) revealed a marginal significant difference between both the groups, \(t(14) = 2.033, p = 0.06\). This suggests that the infants’ specific experience with the weight of the light cube, but not their overall familiarity with it, affected their reaching behaviour.
To further investigate the age differences, we conducted a post-hoc analysis on the 13-month-old infants. As the variance of age in the group of 13-month-old infants (ranging from 12;04 to 13;22) was sufficient for correlational analysis, we analysed the relation between task-performance and age for this group separately. Interestingly, infants’ preference for the object that consists of the same material as the light cube in the exploration phase was positively correlated with the infants’ age, $r = 0.50, p = 0.05$.

GENERAL DISCUSSION

The research presented in this study investigated infants’ ability to use material information to remember and infer the playability of an object. To this end, infants played in an exploration phase with two objects made of different materials. One of the objects was light enough to play with, and the other one was so heavy that it did not allow many actions. When confronted with the same objects again, only the 11-month-old but not the 9-month-old infants were able to use information about an object’s material to remember and to subsequently choose the lighter one. However, when confronted with new objects consisting of the same material, 13-, but not 11-month-old infants transferred this information to the novel objects. Altogether, this indicates that from 11 months on infants use information about an object’s material to remember its affordances and to use this material information to guide their actions.

Importantly, an analysis of infants’ behaviour during the exploration phase clearly suggests that their preference for the lighter object during the test trials is guided by infants’ experiences with the objects’ weight, not by their overall familiarity with the objects. This is important to note as one could assume that the playability of the light object encouraged the infants to be more manually engaged with it and became thus more familiar with the light object than with the heavy object. This would lead to infants eventually choosing the lighter object in the test phase. This conclusion, however, is not supported by our data. Our finding of a relation between infants’ weight-specific exploratory activities and their test performance shows rather the importance of infants’ (manual) exploratory activities and not of their overall engagement for their subsequent goal directed actions (cf. Adolph, Eppler, Marin, Weise, & Clearfield, 2000; Gibson, 1988).

Despite the clear importance of haptic exploration, it should be noted that infants’ ability to solve the task is based on a complex interplay of vision and haptic systems. Already in the exploratory phase, the haptic and the visual system are involved in the perception of some of the objects’ material properties, such as their texture, whereas other properties, such as their weight, can primarily be perceived haptically. In the test phase, however, vision plays a major role as infants’ reaching behaviour is triggered by the objects’ visual appearance. To be able to choose the more playable (i.e. lighter) object, infants therefore need to relate a haptically perceived property (weight) to a visual percept of the object. Previous research has shown that infants from their first months of life onward are able to haptically differentiate between different materials and substances (e.g. Bourgeois et al., 2005), as well as to relate haptically perceived material information to visual percepts of the same material (e.g. Gibson & Walker, 1984). The presented results extend these findings by showing that by the end of the first year of life, infants are able to use the purely visual appearance of an object’s material to recall the weight of the object, a primarily haptically perceived property.

Although in the first year of life, infants are already able to haptically differentiate between different objects with respect to their material properties...
(e.g. Bourgeois et al., 2005) or their weights (e.g. Itier et al., 2001), the 9-month-old infants did not use the objects’ material information to remember its weight and playability. Interestingly, the 11-month-old infants were able to remember the weight, but they did not transfer this information to novel objects made of the same material as the 13-month-olds did, suggesting developmental changes in infants’ ability to employ material information to guide their actions. There are several reasons why the 9-month-old infants might not have reached for the lighter object in the test phase. Possibly, they found both objects to the same degree interesting and—although able to remember the weight of each of the objects—reached for both objects to the same extent. In other words, the 9-month-old infants might have simply lacked the motivation to reach for the light object. However, a recent study, in which the differently weighted objects did not differ with respect to their material, but with respect to their colours, provided direct evidence that 9-month-old infants already show a stable preference for the lighter of two objects, when they were able to identify it (Hauf et al., 2010). Furthermore, an analogous developmental pattern as in Experiment 1 was found in Experiment 2 with 11- and 13-month-old infants. This time, however, the 11-month-olds did not reach for the lighter object above chance, whereas they did so in Experiment 1. This suggests that infants’ failure to reach for the lighter objects in the test phases of both experiments is not due to motivational factors, but due to the difficulties imposed by the different tasks.

A more promising explanation for the difference in the reaching behaviour of the 9-month-old infants from that of the 11- and 13-month-old infants who were able to associate an object’s material and weight information concerns the mode of infants’ object processing. In particular, evidence suggests a developmental trend from an analytical to a configural object-processing mode in infancy (cf. Cohen, 1998). The analytical mode describes information processing based on single features, whereas the configural mode describes the recognition of relations between the features and integration of this information into a higher-level representation. Although recent research has pointed out that this developmental shift occurs between 6 and 8 months of age and that redundant visual-haptic information can even facilitate this shift (Jovanovic, Duemmler, & Schwarzer, 2008), the complexity of the reaching task in the presented study might have interfered with a configural processing of the objects’ properties into a single representation. In other words, it might be possible that the integration of information about a primarily haptically perceived object characteristic like weight with information about visual-haptic properties like texture might have been too difficult for the 9-month-old infants, but could be managed by 11- and 13-month-old infants.

The demonstrated age differences are in line with findings, showing the development of infants’ ability to plan their goal-directed action in the second half of the first year of life (e.g. Claxton, Keen, & McCarty, 2003; Hauf & Aschersleben, 2008). Indeed, the presented results go beyond recent findings on infants’ use of material properties to guide their own actions (cf. Berger, Adolph, & Lobo, 2005). In an elegant study, Berger et al. (2005) encouraged 16-month-old infants to cross from one platform to another via a bridge, to which a handrail was attached. Infants showed a higher tendency to cross the bridge with a wooden handrail compared with a bridge with foam or latex handrails. The data reported in this study build on this insofar as they suggest that infants from 11, but not 9 months of age are able to use information of objects’ material to guide their reaching behaviour and actions.

The present results add to our understanding of how infants guide their interactions with the physical world and have implications for research concerning
the development of physical concepts. Even though already younger infants can perceptually differentiate between different materials (e.g. Striano & Bushnell, 2005) and weights (e.g. Itier et al., 2001), our findings demonstrate that infants do not start to use material information to guide their actions with differently weighted objects before 11 months of age. Only at this age, infants become sensitive to the interrelation of an object’s material and its weight and thus used material to remember its weight, which could be interpreted as an important step in the development of the concept of weight. Importantly, only at 13 months of age, infants used information about an object’s material and its weight (i.e. in the training phase) to transfer the weight information to novel objects made of the same material, suggesting that at this age infants start to appreciate the more general relationship between material and weight (cf. Smith, Carey, & Wiser, 1985). Obviously, infants perceive only from this age material information as a valuable predictor of an object’s weight, indicating an important step in the development of a concept of weight (cf. Carey, 2009). Future research is needed to further investigate this developing capacity, preferably by measuring infants’ weight perception more directly (e.g. Forssberg et al., 1992; Mounoud & Bower, 1974).

In summary, this study demonstrates not only the ability to use material information to guide actions that develops around the first birthday but also reveals important developmental differences in the emerging concept of weight between 9-, 11- and 13-month-old infants.

Notes

1. Owing to an experimenter error, for one 11-month-old participant the exploration phase was not recorded. To nevertheless enable a full statistical treatment of this age group, we decided to replace the missing values by the age group’s average values (under the assumption that this infant would have behaved like average).

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